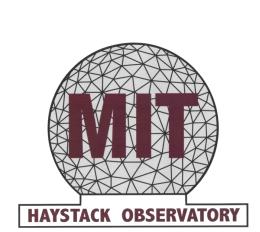# VLBI Observations of the 2010 Chilean Earthquake

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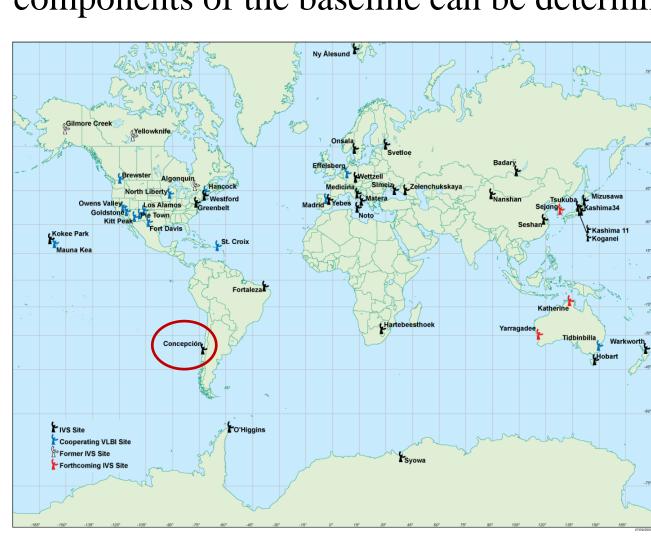
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How Geodetic VLBI Works

The VLBI observable is the difference in the arrival time of a radio signal (from a quasar) at two different radio telescopes. The measured time delay, using the speed of light, can be interpreted as a distance. The distance is the component of the baseline toward the source (quasar). By observing many sources, all components of the baseline can be determined.

Global network of radio telescopes of the International VLBI Service for Geodesy and Astrometry (IVS). IVS Station TIGO is located in Concepción, Chile and is co-located with GNSS and other geodetic instruments.
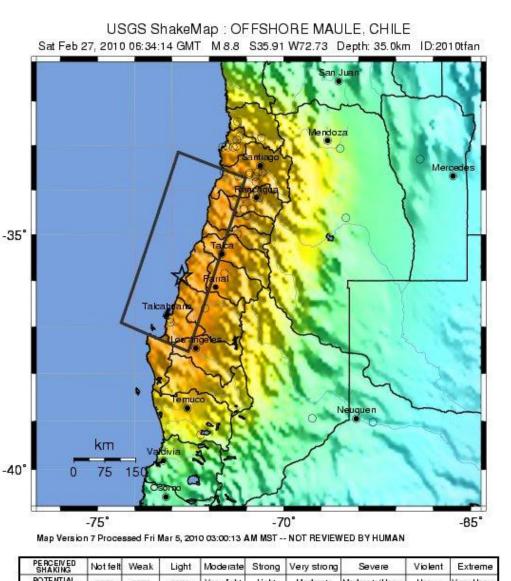
Available VLBI Data

The IVS observes 24-hour sessions on a regular basis typically using a network of 6–8 stations. Per week, about two or three sessions are observed by a given station. TIGO observed until 25 February 2010 (two days before the earthquake), was down for about 2 weeks, and resumed observing on 15 March 2010. The regular 24-hour observing sessions were augmented by five dedicated 3-hour sessions on a smaller network (TQUAK). The main purpose of the TQUAK sessions was to get more data points in the VLBI time series for an improved analysis of the post-seismic behavior of the station.

Observing plan excerpt.

Session	Date	Start time	Duration
T2067	FEB02	17:30 UT	24 hours
OHIG67	FEB03	18:00 UT	24 hours
OHIG68	FEB09	17:30 UT	24 hours
OHIG69	FEB10	18:00 UT	24 hours
R4417	FEB11	18:30 UT	24 hours
RD1002	FEB17	17:30 UT	24 hours
R4418	FEB18	18:30 UT	24 hours
R1419	FEB22	17:00 UT	24 hours
R4419	FEB25	18:30 UT	24 hours
R1422	MAR15	17:00 UT	24 hours
R4422	MAR18	18:30 UT	24 hours
R1423	MAR22	17:00 UT	24 hours
TQUAK01	MAR23	20:00 UT	3 hours
TQUAK02	MAR24	20:00 UT	3 hours
R4423	MAR25	18:30 UT	24 hours
TQUAK03	MAR26	20:00 UT	3 hours
R1424	MAR29	17:00 UT	24 hours
TQUAK04	MAR30	20:00 UT	3 hours
R4424	MAR31	18:30 UT	24 hours
TQUAK05	APR01	20:00 UT	3 hours
R1425	APR06	17:00 UT	24 hours

Typical 24-hour session network.
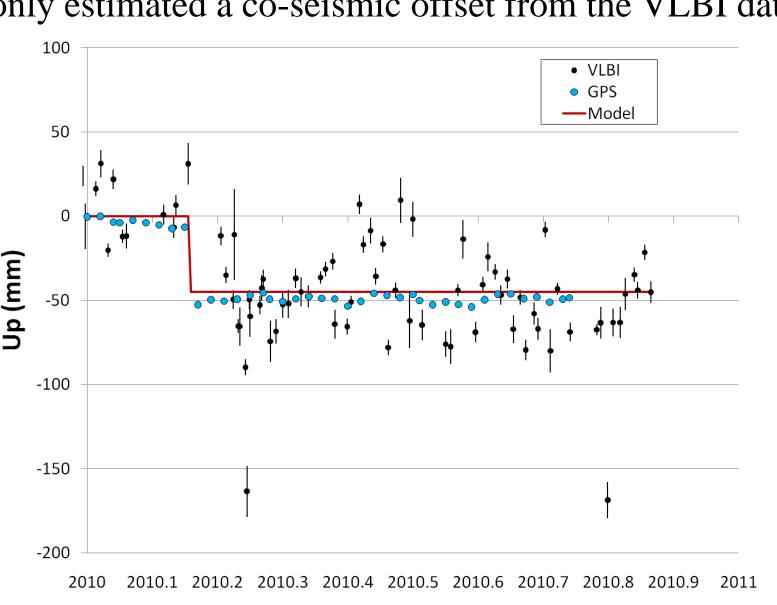

TQUAK 3-hour session network.

Photo of the VLBI antenna at TIGO.

The epicenter of the magnitude 8.8 earthquake on February 27, 2010 at 06:34:14 UTC (03:34:14 local time) was located in a depth of about 35 km at 35.846°S and 72.719°W. This location is about 115 km NNE of the city of Concepción, which is the host city of the geodetic observatory TIGO.

VLBI Results

In our standard terrestrial reference frame CALC/SOLVE solutions, we estimate site positions and velocities as global parameters. To investigate the behavior of the position of TIGOCONC, we modified the solution to estimate the TIGOCONC position for each epoch (VLBI 24-hour experiment). We now have about 9 months of data since the earthquake. In the Figures below are shown our latest solution for the local site coordinate series for TIGOCONC. Offsets, rates, and annual terms were estimated from data (VLBI or GPS) before the earthquake and removed from each series. We have compared the post-seismic trends from VLBI and GPS measurements. In the Figures below, we show weekly-averaged DGFI analysis series (courtesy of Laura Sanchez).

For East motion, there is clear nonlinear variation after the earthquake; whereas, the motion in the vertical and North is linear and at the same rate as before the earthquake. For the North and Up components, we only estimated a co-seismic offset from the VLBI data.
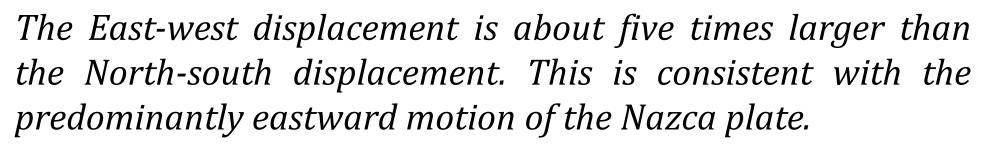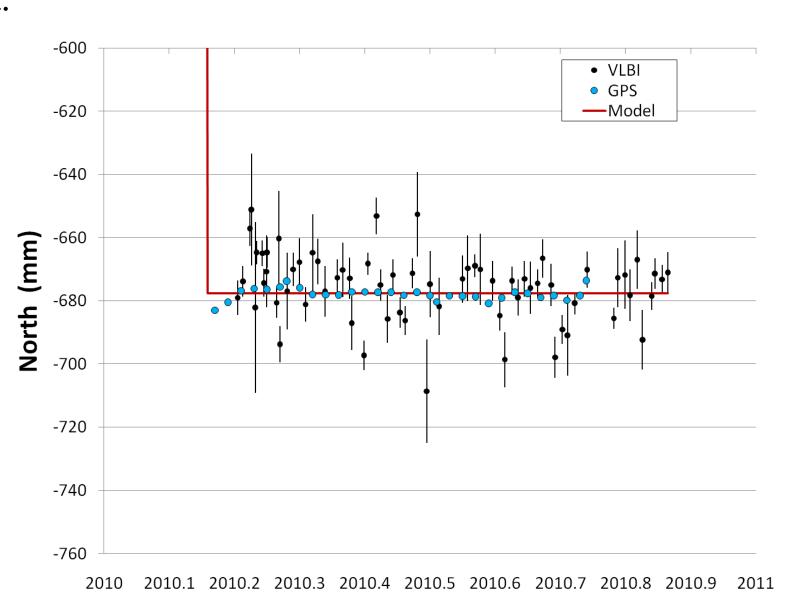

	Up	North
VLBI	−45 mm ± 3 mm	−678 mm ± 2 mm
GPS	−49 mm ± 1 mm	−678 mm ± 1 mm

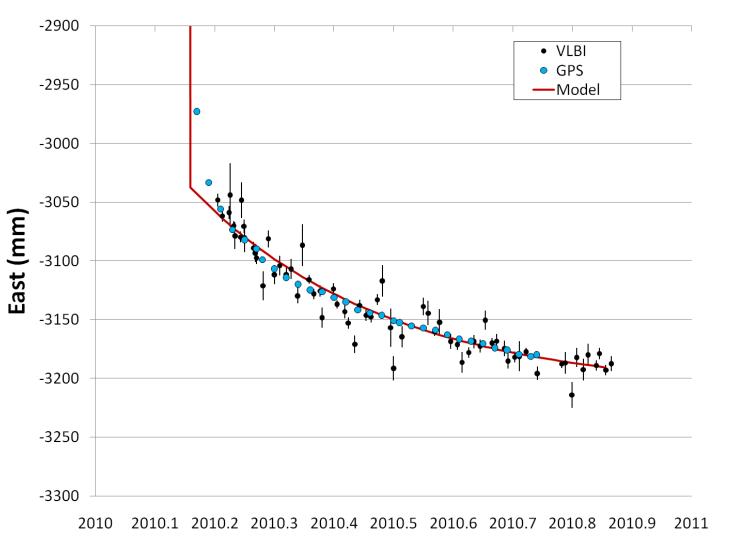For East, we fit the post-seismic VLBI data using a transient decay model,

$$X(t) = X_0 + X_1 \left[1 - \exp((t-t_0)/\tau_c) \right],$$

where t_0 is the epoch of the earthquake. The fit gave a characteristic decay times, τ_c, of 117 days. The post-seismic amplitudes, X_1, assuming this model was −174 mm. The co-seismic offset, X_0, was −3038 mm. This model fits the data fairly well for times greater than about 1 month after the earthquake.
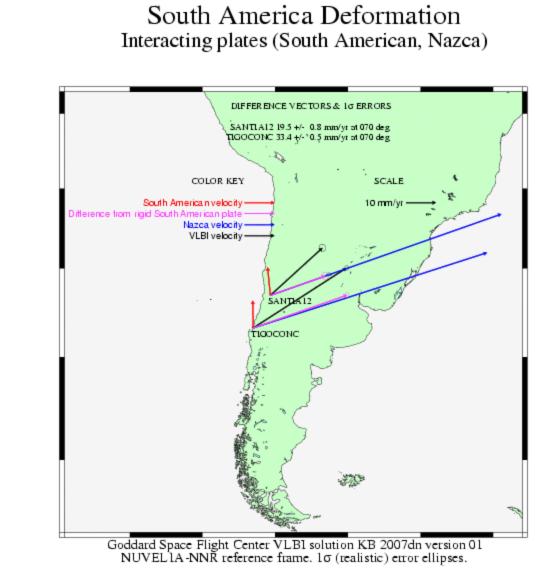

In general there is good agreement between the trends of the two series. The first post-earthquake GPS point is the average of the data from the first week after the earthquake. However, the first 2–3 weeks of GPS values indicate that the East position decreased more sharply than the above transient model.
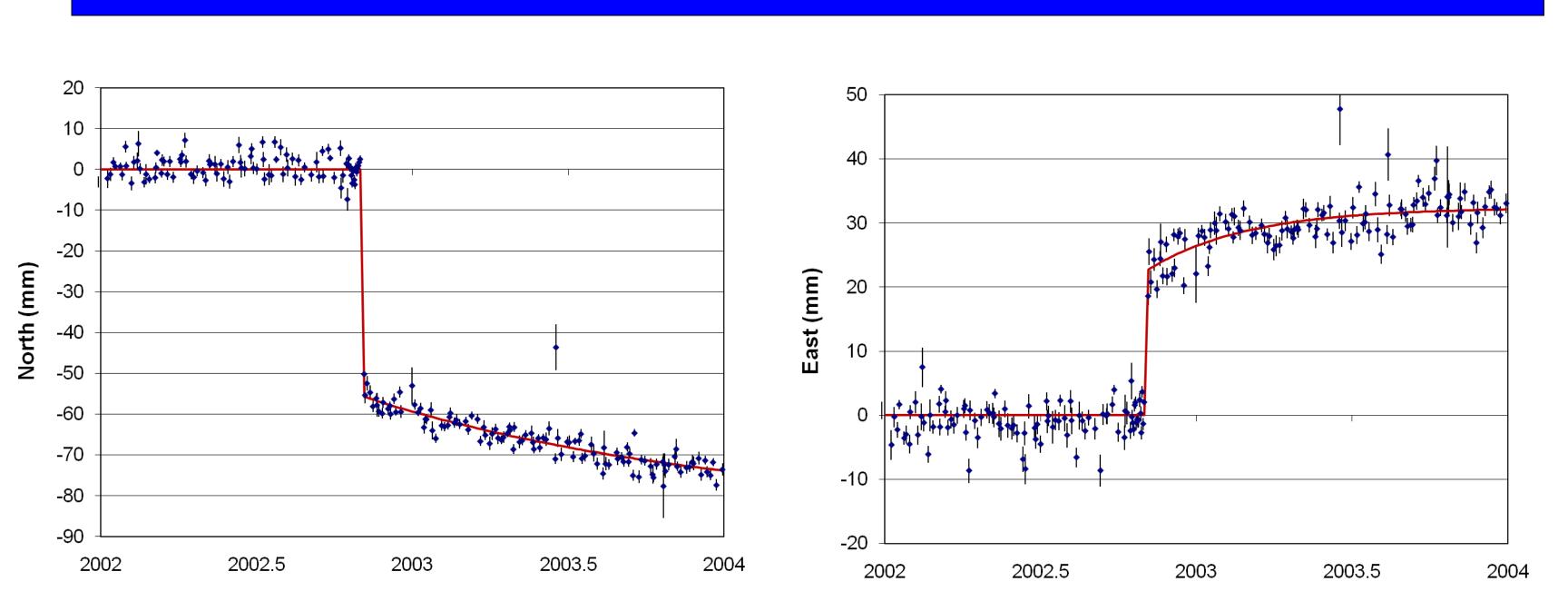
South America Deformation
Interacting plates (South American, Nazca)

The East-west displacement is about five times larger than the North-south displacement. This is consistent with the predominantly eastward motion of the Nazca plate.

Comparison with Denali Earthquake Results

For comparison, we show the VLBI horizontal position series for GILCREEK (Fairbanks) in the time frame of the Denali fault earthquake (Nov. 3, 2002). The Fairbanks antenna position is about 150 km north of the Denali fault and from the earthquake epicenter.

The fits of the post-seismic data gave characteristic decay times, τ_c, of 429 days for the North and 117 days for the East. The post-seismic amplitudes, X_1, assuming this model were −29 mm in the North and 10 mm in the East. (Co-seismic offsets, X_0, were −56 mm and 23 mm for North and East respectively.) Since Fairbanks is much further from the earthquake epicenter, the co-seismic offsets are an order of magnitude smaller than what we see for TIGOCONC.

Conclusions and Future Work

We described the available VLBI data for the station TIGOCONC collected prior to and after the major earthquake. Five dedicated sessions were added to the IVS observing program in order to densify the data points in the VLBI time series. The VLBI data indicate that the Up and North components of the position time series can be modeled as a co-seismic offset. The East component, however, needs to be modeled using, for instance, a transient decay model for the post-seismic effect.

The comparison of the session-wise organized VLBI data with GPS was done with weekly averages for the GPS data. We intend to extend the comparison to daily average for GPS. In particular, for the East component it will be important to have data points for the time series closer to the earthquake event in order to be able to improve the modeling of the post-seismic relaxation.

We also intend to analyze how the estimation of the Earth orientation parameters (EOP) will be impacted if no transient decay model but rather an offset is used in the VLBI data analysis.

Acknowledgement

We would like to thank the station personnel of the Geodetic Observatory TIGO for bringing the VLBI system online so fast after the earthquake and the Universidad de Concepción for the full support they provided in order to make this happen.